Coastal Aerosol Distribution By Data Assimilation

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LONG-TERM GOAL

The long-term goal of this research is to develop an initialization scheme for a multi-dimensional, predictive aerosol model in coastal regions. The initialization scheme will have global coverage and include data gathering, quality control and data assimilation of the available aerosol observations, including satellite aerosol retrievals, ground-based remote sensing, point measurements, and the previous aerosol forecast.

OBJECTIVES

The objectives of this program are to (1) investigate and evaluate the existing and proposed aerosol retrievals from satellites for applicability to aerosol model initialization and (2) develop and test aerosol analysis and data assimilation techniques using satellite and other aerosol measurements.

APPROACH

The approach to the problem of aerosol and Electro-Optical (EO) extinction prediction follows that used in numerical weather prediction, namely real-time assessment and first-principle modeling. A predictive model requires the initial spatial distribution of the aerosol field including composition, concentration, and size distribution. Sensors and retrieval techniques exist for obtaining the aerosol optical depth and some information about particle size. The remotely sensed aerosol properties typically are vertical integrals and are generated at horizontal resolutions ranging from one kilometer to one degree. An objective analysis method is being devised to merge these 2-D distributions with point measurements and model constraints to produce a three-dimensional description of aerosols.

WORK COMPLETED

A prototype forecast version of the Navy Atmospheric Aerosol Prediction System, NAAPS, was developed and tested during PRIDE (Puerto Rico Dust Experiment). Every 12 hours, a five-day forecast was carried out, based on the Navy Operational Global Atmospheric Prediction System (NOGAPS) forecast fields. The forecasts were automatically plotted and displayed on a web site for use in operational planning by the PRIDE science team during the experiment.

The US Geological Survey (USGS)/NRL landuse database (with seasonal adjustments by T. Holt) has been used to specify monthly values of surface roughness. These in turn are used to retrieve the

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14. ABSTRACT
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15. SUBJECT TERMS

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surface stress from the Navy Operational Global Atmospheric Prediction System (NOGAPS) 10-meter wind field and stability. This approach allows both seasonal and diurnal variations in NAAPS surface processes such as dust mobilization and dry deposition. A method has been developed for using TOMS (Total Ozone Mapping Spectrometer) data to refine the dust source region for the Sahara and Southwest Asia. A year's worth of data were used to identify the source regions by looking for persistent hot spots. The same methodology will be used to refine dust source regions in other parts of the world.

The GSFC (Goddard Space Flight Center)/TOMS AI (Absorbing Aerosol Index) is now received in digital form each day and compared pixel-by-pixel with NAAPS, as has been done with the NOAA AOD (Aerosol Optical Depth) product since the previous year. This comparison quantified what we knew from subjective comparisons: without biomass smoke sources, NAAPS was missing some of highest optical depths observed in the world. In response to the shortcoming regarding smoke, the ABBA (Automated Biomass Burning Algorithm) product for fire detection in the western hemisphere based on GOES data is now received every half hour at NRL from University of Wisconsin. (Last year it was available only four times daily and only for South America.) This product will be used to specify western hemispheric smoke sources in NAAPS after we assign emission factors for all of the possible biomes. A historical dataset (1993) for fires in Africa, Indonesia, and Australia was received from the European Space Agency (ESA) and is used to specify smoke sources in those regions. A program to detect biomass fires from AVHRR Global Area Coverage (GAC) data received daily from Naval Oceanographic Office (NAVO) has been ported to NRL from U. A. Huntsville to provide once-daily global coverage at coarse resolution. After being evaluated over North America using the ABBA product, it will be used to provide fire locations in the rest of the world. Displays of the ABBA fire locations were added to the NAAPS web page (http://www.nrlmry.navy.mil/aerosol.)

Displays of NAAPS side-by-side with satellite imagery for the tropical Atlantic Ocean and North America were added to the NAAPS web page. The NAAPS comparison plots facilitate the study of Saharan dust plumes (e.g. Figure 1) and the large Montana smoke plumes (August, 2000), respectively.

An algorithm for estimating extinction from surface synoptic reports of visibility, weather and humidity was developed by Washington University and implemented at NRL for validation and initialization of NAAPS.

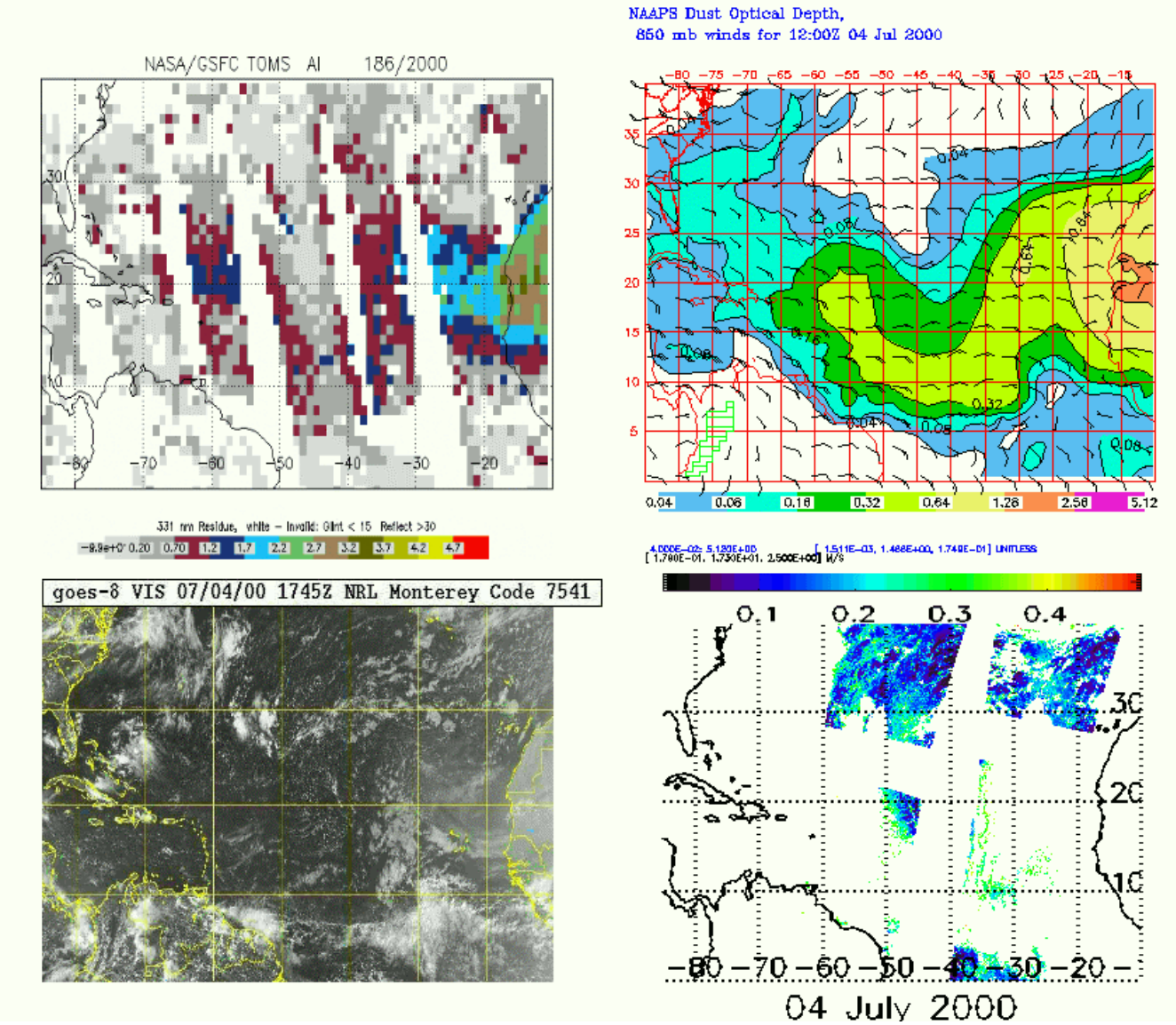

Figure 1. NAAPS-Satellite comparison for July 4, 2000. Top-left panel: GSFC TOMS AI, shows distribution of absorbing (dust) aerosols; top-right panel: NAAPS simulated aerosol optical depth showing distribution of dust optical depth, con toured at 0.04, 0.08, 0.16 etc. and 850 hPa winds; bottom-left panel: GOES visible imagery; bottom-right panel: SeaWiFS optical depth. The images show an dust outbreak just off the African coast trailing an earlier one which has just reach Puerto Rico. Note the interaction with mid-latitude air along the northern boundary and the effects of the tropical wave located at 10N, 25W. The SeaWiFS retrieval has poor coverage due to the presence of clouds and high dust optical depths.

RESULTS

A goal of the Puerto Rico Dust Experiment (PRIDE) was to gather data for validation of dust forecasts by the Navy Aerosol Analysis and Prediction System, or NAAPS, a global aerosol forecast model. A detailed, quantitative validation of the amount, vertical and horizontal distribution, timing, and frequency of the forecasted Sahara dust events in the Caribbean region will be possible after the

surface, aircraft, and satellite data from PRIDE are analyzed. Modeling these events is difficult due to their distant origins, some 5000 km to the east in the unpopulated Sahara, and due to the subsequent week-long transport to Puerto Rico. A pixel-by-pixel comparison with TOMS and AVHRR satellite data and AERONET sunphotometer data shows that NAAPS captures the main features of the major dust events that occurred during PRIDE, though the satellite data are insufficient to verify the detailed structure contained in the simulations. The daily simulations reveal some new aspects of Saharan dust events. Strong interactions occur with the mid-latitude systems with dust drawn north of 30N ahead of troughs. At other times, clean mid-latitude air is sent south of 20N directly into the outbreak. The forecasts and satellite data show that the peak dust concentrations at Puerto Rico occur just after the passage of the an easterly wave. The forecasted peak is followed by a minima and then another relative maxima ahead of the next easterly wave. The intervening minima may be due to the injections of relatively clean air from the north. As a measure of the fidelity of the successive forecasts, we have compared the NAAPS 24- through 120-hour forecasts for the same time and find good agreement, except for one case with a poorly forecasted tropical wave.

NAAPS has been run daily for the entire fiscal year producing realistic simulations of the global distribution of sulfate, dust, and smoke aerosols. This continuous modeling continues to reveal unexpected cases of inter-continental aerosol transport. These include the transport of Asian dust and pollution across North America to the Atlantic Ocean and transport of Saharan dust to the Eastern Seaboard via Europe and the North Atlantic.

IMPACT/APPLICATION

Presently, NAAPS produces simulations of the current global aerosol distribution. A prototype version is running in a predictive mode and help to satisfy the Navy's long-term goal of a predictive capability for aerosols and EO propagation. This research also provides tools for the 6.1 and 6.2 aerosol research communities and the academic community. As NAAPS has been discovered, collaborations have been initiated between NRL and University of Miami, State of Vermont, University of Colorado, Texas Tech. University, JPL, Scripps Institute, University of Rhode Island, Washington University, GSFC, and others; NRL has been invited to participate in ACE-Asia and was invited to the First International Conference on Trans-Pacific Transport of Atmospheric Pollutants.

TRANSITIONS

The NAAPS simulations and retrieval techniques can soon provide operational aerosol products showing the distribution of anthropogenic, smoke, dust and other aerosols that can be dissemination to the fleet for use in tactical, strategic and defense planning, for use in dust screening in SST retrievals and in Electro Optical Tactical Decision Aid (EOTDA) validation and development. Funding for this transition is being obtained through the ONR/SPAWAR Rapid Transition Program for FY01.

RELATED PROJECTS

The NRL 6.1 Coastal Aerosol Processes ARI (BE-033-02-4K) and NRL BE-35-2-18, Mesoscale Modeling of the Atmosphere and Aerosols use NAAPS and the satellite retrievals for investigations and validation. When developed, the operational retrievals and the data assimilation product will be invaluable to these programs. This work is also relevant to 6.4 efforts in EOTDA evaluation and aerosol measurement (PE 0603207N, SPAWAR PMW-185).

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